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Lensing results from the Red-sequence Cluster Survey

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Abstract.

We present a variety of weak lensing results based on the ongoing analysis of R_C-band imaging data from the Red-Sequence Cluster Survey (RCS). We briefly discuss the weak lensing signal induced by intervening large scale structure (cosmic shear), and study the properties of the dark matter halos surrounding galaxies with $19.5 < R_C < 21$ (which have a median redshift of $z = 0.35$) using a parametrized mass model for the galaxy mass distribution. This allows us for the first time to constrain the extent of the halos. We find a robust upper limit for the truncation parameter $s < 470h^{-1}$ kpc (99.7% confidence). We also study the biasing properties of these galaxies as a function of scale. We find that both the bias parameter b and the galaxy-mass cross-correlation coefficient r vary with scale (on scales $0.1 - 6\ h^{-1}$ Mpc). Interestingly, we find that $r = 0.57^{+0.08}_{-0.07}$ on scales $\sim 0.5h^{-1}$ Mpc.

1. Introduction

The Red-Sequence Cluster Survey[1] (e.g., Gladders & Yee 2000) is the largest area, moderately deep imaging survey ever undertaken on 4m class telescopes. The planned survey comprises 100 square degrees of imaging in 2 filters (22 widely separated patches imaged in R_C and z'), and will provide a large sample of optically selected clusters of galaxies with redshifts $0.1 < z < 1.4$.

The survey allows a variety of studies, such as constraining cosmological parameters from the measurement of the evolution of the number density of galaxy clusters as a function of mass and redshift, and studies of the evolution of cluster galaxies, blue fraction, etc. at redshifts for which very limited data are available at present.

The data are also useful for a range of lensing studies. Strong lensing by clusters of galaxies allows a detailed study of their core mass distribution. In addition, given the shallowness of the survey, the arcs are sufficiently bright to be followed up spectroscopically (Gladders, Yee, & Ellingson 2001). Thanks to

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[1]`http://www.astro.utoronto.ca/~gladders/RCS`

the large magnifications of the arcs, the survey allows unprecedented studies of the properties of high redshift galaxies. Furthermore, in combination with detailed modeling of the cluster mass distribution, the geometry of the images can be used to constrain Ω_m.

In these proceedings we concentrate on some of the weak lensing applications. A detailed description of the data and the weak lensing analysis is presented in Hoekstra et al. (2002a). A careful examination of the residuals suggests that the object analysis, and the necessary corrections for observational distortions work well, which allows us to obtain accurate measurements of the weak lensing signal.

2. Measurement of Cosmic Shear

The weak distortions of the images of distant galaxies by intervening matter provide an important tool to study the projected mass distribution in the universe and constrain cosmological parameters (e.g., van Waerbeke et al. 2001). Compared to other studies, the RCS data are relatively shallow, resulting in a lower cosmic shear signal. However, the redshift distribution of the source galaxies, which is needed to interpret the results, is known fairly well.

We use the photometric redshift distribution inferred from the Hubble Deep Field North and South to compare the observed lensing signal to CDM predictions. For an $\Omega_m = 0.3$ flat model we obtain $\sigma_8 = 0.81^{+0.14}_{-0.19}$ (95% confidence), in good agreement with the measurements of van Waerbeke et al. (2001). A detailed discussion of this measurement is presented in Hoekstra et al. (2002a).
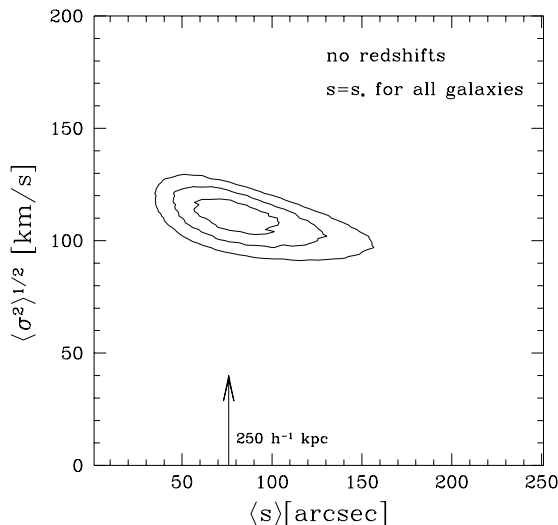

Figure 1.   Likelihood contours for the mass weighted velocity dispersion, and the average value of the truncation parameter s for galaxies with $19.5 < R_C < 21$. We have also indicated the physical scale when s is the same for all galaxies. The contours indicate 68.3%, 95.4%, and 99.7% confidence limits on two parameters jointly.

3.   Galaxy-Galaxy Lensing

Weak lensing is also an important tool to study the dark matter halos of field (spiral) galaxies. The weak lensing signal can be measured out to large projected distances. Hence it provides a powerful probe of the gravitational potential at large radii. Unfortunately, the lensing signal induced by an individual galaxy is too low to be detected, and one can only study the ensemble averaged signal around a large number of lenses.

The results presented here are based on 16.4 deg^2 of CFHT data. We use galaxies with $19.5 < R_C < 21$ as lenses, and galaxies with $21.5 < R_C < 24$ as sources which are used to measure the lensing signal. The redshift distribution of the lenses is known spectroscopically from the CNOC2 field galaxy redshift survey (e.g., Yee et al. 2000), and for the source redshift distribution we use the photmetric redshift distribution from the HDF North and South. The adopted redshift distributions give a median redshift $z = 0.35$ for the lens galaxies, and $z = 0.53$ for the source galaxies.

We use a parametrized mass model with a (smoothly) "truncated" halo to study the properties of the dark matter halos surrounding the sample of lens galaxies. The results are presented in Figure 1. With the adopted redshift distribution we obtain $\langle\sigma^2\rangle^{1/2} = 111 \pm 5$ km/s. It turns out that the quoted value is close to that of an L^* galaxy, and our results are in fair agreement with other estimates.

In addition, for the first time, the average extent of the dark matter halo has been measured. Under the assumption that all halos have the same truncation parameter, we find a 99.7% confidence upper limit of $\langle s\rangle < 470h^{-1}$ kpc. More realistic scaling relations for s give lower values for the physical scale of $\langle s\rangle$, and therefore the result presented here can be interpreted as a robust upper limit.

4.   Measurement of Galaxy Biasing

The relation between the galaxy distribution and the dark matter distribution (i.e., galaxy biasing) is intimately linked to the details of galaxy formation. Most current constraints come from dynamical measurements that probe relatively large scales ($\geq$ a few Mpc). Weak lensing provides a unique and powerful way to study the biasing properties of galaxies on smaller scales.

Through weak lensing we can measure the bias parameter b (which corresponds to the linear regression of the mass density contrast and the galaxy density contrast) and the galaxy-mass cross-correlation coefficient r (which mixes non-linear and stochastic biasing) as a function of scale.

The RCS alone provides an accurate measurement of the ratio b/r, and the first results were published in Hoekstra et al. (2001). However, combining the RCS measurements with the results from the VIRMOS-DESCART survey (van Waerbeke et al. 2001), allows a determination of b and r separately. The results presented in Figure 2 are based on 45 deg^2 of RCS data and 6.5 deg^2 of VIRMOS-DESCART data.

We find that b changes with scale for our sample of lens galaxies ($19.5 < R_C < 21$), which have luminosities around L^*. For the currently favored cosmology ($\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$), we find $b = 0.71^{+0.06}_{-0.05}$ (68% confidence) on a scale
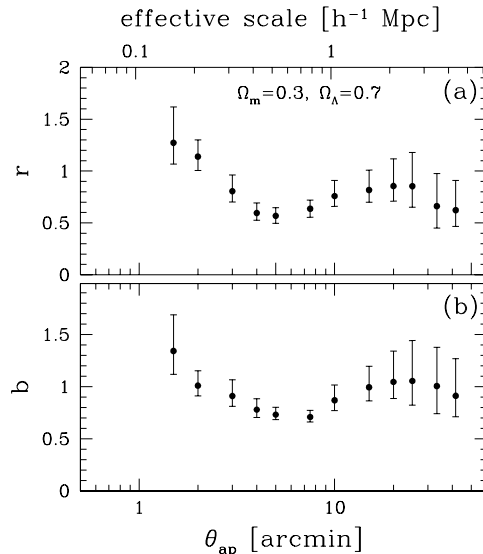
Figure 2.   (a) The measured value of the galaxy-mass cross correlation coefficient r as a function of scale for the ΛCDM cosmology. (b) The bias parameter b as a function of scale. The upper axis indicates the effective physical scale probed by the compensated filter at the median redshfit of the lenses ($z = 0.35$). The errorbars correspond to the 68% confidence intervals. Note that the measurements at different scales are slightly correlated.

of $0.5 - 1h^{-1}$ Mpc, increasing to ~ 1 on larger scales. The value of r hardly depends on the assumed cosmology, and we find that $r \sim 1$ on scales less than $250h^{-1}$ kpc. Hence, we "find" a halo around every (massive) galaxy. However, on larger scales ($\sim 0.5h^{-1}$ Mpc) r is significantly lower than unity (we find a minimum value of $r = 0.57^{0.08}_{-0.07}$), thus suggesting significant stochastic biasing and/or non-linear biasing. On even larger scales ($> 2h^{-1}$Mpc) the value of r is lower, but consistent with $r = 1$. As r is linked intimately to the details of galaxy formation, our results provide unique constraints on such models. A detailed discussion of these measurements can be found in Hoekstra et al. (2002b).

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